

C L A I M S

1. An estimation system for estimating an
2 object state, characterized by comprising:
3 image input means for inputting an input image
4 containing an object whose state is to be estimated, the
5 state being at least one of a position and posture;
6 3D shape data storage means for storing 3D
7 shape data of the object;
8 comparison image generation means for
9 generating, as a comparison image, an image containing
10 the object in a predetermined state by using the 3D
11 shape data stored in said 3D shape data storage means;
12 image positional relationship detection means
13 for detecting, for each sub-region having a
14 predetermined size in the image, a positional
15 relationship between the input image and the comparison
16 image generated by said comparison image generation
17 means;
18 correction amount calculation means for
19 calculating a correction amount of the object state in
20 the comparison image by using the positional
21 relationship detected by said image positional
22 relationship detection means; and
23 state correction means for correcting the
24 object state set in comparison image generation by said
25 comparison image generation means by using the
26 correction amount obtained by said correction amount

27 calculation means, thereby calculating a new object
28 state.

2. An estimation system for estimating an
2 object state according to claim 1, characterized by
3 further comprising state determination means for
4 determining on the basis of the correction amount
5 obtained by said correction amount calculation means
6 whether the object state set by said comparison image
7 generation means is appropriate,
8 wherein when it is determined that the object
9 state is appropriate, the object state set by said
10 comparison image generation means is output as an
11 estimation value, and
12 when it is determined that the object state is
13 not appropriate, estimation processing including the
14 comparison image generation processing by said
15 comparison image generation means, the positional
16 relationship detection processing by said image
17 positional relationship detection means, and the
18 correction amount calculation processing by said
19 correction amount calculation means is executed again by
20 setting the new object state calculated by said state
21 correction means to the predetermined state.

3. An estimation system for estimating an
2 object state according to claim 2, characterized in that
3 said state determination means determines that the
4 object state is appropriate when the correction amount

5 obtained by said correction amount calculation means is
6 smaller than a predetermined amount, and determines that
7 the object state is not appropriate when the correction
8 amount is not smaller than the predetermined amount.

4. An estimation system for estimating an
2 object state according to claim 2, characterized by
3 further comprising:

4 first similarity calculation means for
5 calculating a first similarity between the comparison
6 image and the input image after the estimation
7 processing is executed again; and

8 second similarity calculation means for
9 calculating a second similarity between the comparison
10 image and the input image before the estimation
11 processing is executed again,

12 wherein said state determination means
13 compares the first similarity with the second
14 similarity, determines that the object state is not
15 appropriate when the first similarity is higher than the
16 second similarity, and determines that the object state
17 is appropriate when the first similarity is not higher
18 than the second similarity.

5. An estimation system for estimating an
2 object state according to claim 1, wherein

3 said image input means comprises means for
4 inputting a moving image containing an object, and

5 said image positional relationship detection

6 means uses a latest frame image of the moving image as
7 the input image.

6. An estimation system for estimating an
2 object state according to claim 1, characterized in that
3 said comparison image generation means comprises:

4 means for reproducing a luminance value of an
5 object surface, which changes depending on an
6 illumination condition; and

7 means for generating the comparison image
8 under an illumination condition close to that for the
9 input image by using the reproduced luminance value.

7. An estimation system for estimating an
2 object state according to claim 6, characterized by
3 further comprising illumination base image group storage
4 means for storing an illumination base image group
5 representing a variation in luminance of the object
6 surface depending on the illumination condition,
7 wherein said comparison image generation means
8 reproduces the luminance value of the object surface by
9 using the illumination base image group stored in said
10 illumination base image group storage means.

8. An estimation system for estimating an
2 object state according to claim 7, characterized by
3 further comprising:

4 3D shape measuring means for measuring the 3D
5 shape data of the object and reflectance data of the
6 object surface; and

7 illumination base calculation means for
8 calculating an illumination base image representing the
9 variation in luminance of the object surface depending
10 on the illumination condition by using the 3D shape data
11 and the reflectance data of the object surface which are
12 measured by said 3D shape measuring means.

9. An estimation system for estimating an
2 object state according to claim 8, characterized in that
3 said illumination base calculation means
4 calculates a vector group representing the luminance
5 value of each point of the 3D shape data under a
6 plurality of illumination conditions, obtains a base
7 vector group in descending order of eigenvalues by
8 principal component analysis of the vector group, and
9 outputs the base vector group as the illumination base
10 image group, and

11 said comparison image generation means
12 obtains, by using the 3D shape data of the object, a
13 correspondence between each point of the 3D shape data
14 of the object and a pixel of the image with the object
15 being in an estimation value at current time, generates,
16 by using the correspondence, an image illumination base
17 group in which the illumination base image group is
18 projected to the image with the object being in the
19 estimation value, and generates, as the comparison
20 image, an image nearest to the input image by linear
21 connection of the image illumination base group.

10. An estimation system for estimating an
2 object state according to claim 1, characterized in that
3 said correction amount calculation means calculates, as
4 the correction amount, a 3D motion of the object which
5 causes a moving amount of an object part corresponding
6 to each sub-region in the comparison image to be near to
7 an image displacement distribution by using the 3D shape
8 data of the object and the image displacement
9 distribution representing the positional relationship
10 between the comparison image and the input image for
11 each sub-region.

11. An estimation system for estimating an
2 object state according to claim 1, characterized by
3 further comprising feature extraction means for
4 extracting an image feature amount of each of the input
5 image and comparison image on the basis of luminance
6 values of the input image and the comparison image
7 generated by said comparison image generation means,
8 wherein said image positional relationship
9 detection means detects the positional relationship
10 between the input image and the comparison image for
11 each sub-region on the basis of the image feature amount
12 extracted by said feature extraction means.

12. An estimation method of estimating an
2 object state, characterized by comprising the steps of:
3 inputting an input image containing an object
4 whose state is to be estimated, the state being at least

5 one of a position and posture;
6 generating, as a comparison image, an image
7 containing the object in a predetermined state by using
8 3D shape data of the object;
9 detecting a positional relationship between
10 the comparison image and the input image for each
11 sub-region having a predetermined size in the image;
12 calculating a correction amount of the object
13 state in the comparison image by using the detected
14 positional relationship; and
15 correcting the object state set in comparison
16 image generation by using the calculated correction
17 amount, thereby calculating a new object state.

13. An estimation method of estimating an
2 object state according to claim 12, characterized by
3 further comprising the steps of:
4 determining on the basis of the calculated
5 correction amount whether the object state set in
6 comparison image generation is appropriate; and
7 outputting the object state set in comparison
8 image generation as an estimation value when it is
9 determined that the object state is appropriate,
10 wherein when it is determined that the object
11 state is not appropriate, estimation processing
12 including the step of generating the comparison image,
13 the step of detecting the positional relationship, and
14 the step of calculating the correction amount is

15 executed again by setting the calculated new object
16 state to the predetermined state.

14. An estimation method of estimating an
2 object state according to claim 13, characterized in
3 that in the determination step, it is determined that
4 the object state is appropriate when the correction
5 amount is smaller than a predetermined amount, and it is
6 determined that the object state is not appropriate when
7 the correction amount is not smaller than the
8 predetermined amount.

15. An estimation method of estimating an
2 object state according to claim 13, characterized by
3 further comprising the steps of:
4 calculating a first similarity between the
5 comparison image and the input image after the
6 estimation processing is executed again; and
7 calculating a second similarity between the
8 comparison image and the input image before the
9 estimation processing is executed again,
10 wherein in the determination step, the first
11 similarity is compared with the second similarity, it is
12 determined that the object state is not appropriate when
13 the first similarity is higher than the second
14 similarity, and it is determined that the object state
15 is appropriate when the first similarity is not higher
16 than the second similarity.

16. An estimation method of estimating an

2 object state according to claim 12, wherein
3 in the step of inputting the image, a moving
4 image containing an object is input, and
5 in the step of detecting the positional
6 relationship, a latest frame image of the moving image
7 is used as the input image.

17. An estimation method of estimating an
2 object state according to claim 12, characterized in
3 that the step of generating the comparison image
4 comprises the steps of:
5 reproducing a luminance value of an object
6 surface, which changes depending on an illumination
7 condition; and
8 generating the comparison image under an
9 illumination condition close to that for the input image
10 by using the reproduced luminance value.

18. An estimation method of estimating an
2 object state according to claim 17, characterized in
3 that in the step of generating the comparison image, the
4 luminance value of the object surface is reproduced by
5 using an illumination base image group representing a
6 variation in luminance of the object surface depending
7 on the illumination condition.

19. An estimation method of estimating an
2 object state according to claim 18, characterized by
3 further comprising the steps of:
4 measuring the 3D shape data of the object and

5 reflectance data of the object surface; and
6 calculating an illumination base image
7 representing the variation in luminance of the object
8 surface depending on the illumination condition by using
9 the 3D shape data and the reflectance data of the object
10 surface.

20. An estimation method of estimating an
2 object state according to claim 19, characterized in
3 that
4 in the step of calculating the illumination
5 base image, a vector group representing the luminance
6 value of each point of the 3D shape data under a
7 plurality of illumination conditions is calculated, a
8 base vector group is obtained in descending order of
9 eigenvalues by principal component analysis of the
10 vector group, and the base vector group is output as the
11 illumination base image group, and
12 in the step of generating the comparison
13 image, a correspondence between each point of the 3D
14 shape data of the object and a pixel of the image with
15 the object being in an estimation value at current time
16 is obtained by using the 3D shape data of the object, an
17 image illumination base group in which the illumination
18 base image group is projected to the image with the
19 object being in the estimation value is generated by
20 using the correspondence, and an image nearest to the
21 input image is generated as the comparison image by

22 linear connection of the image illumination base group.

21. An estimation method of estimating an
2 object state according to claim 12, characterized in
3 that in the step of calculating the correction amount, a
4 3D motion of the object which causes a moving amount of
5 an object part corresponding to each sub-region in the
6 comparison image to be near to an image displacement
7 distribution is calculated as the correction amount by
8 using the 3D shape data of the object and the image
9 displacement distribution representing the positional
10 relationship between the comparison image and the input
11 image for each sub-region.

22. An estimation method of estimating an
2 object state according to claim 12, characterized by
3 further comprising the step of extracting an image
4 feature amount of each of the comparison image and input
5 image on the basis of luminance values of the comparison
6 image and input image,

7 wherein in the step of detecting the
8 positional relationship, the positional relationship
9 between the input image and the comparison image for
10 each sub-region is detected on the basis of the image
11 feature amount.

23. An estimation program for estimating an
2 object state, which causes a computer to execute the
3 steps of:

4 inputting an input image containing an object

5 whose state is to be estimated, the state being at least
6 one of a position and posture;
7 generating, as a comparison image, an image
8 containing the object in a predetermined state by using
9 3D shape data of the object;
10 detecting a positional relationship between
11 the comparison image and the input image for each
12 sub-region having a predetermined size in the image;
13 calculating a correction amount of the object
14 state in the comparison image by using the detected
15 positional relationship; and
16 correcting the object state set in comparison
17 image generation by using the calculated correction
18 amount, thereby calculating a new object state.

24. An estimation program for estimating an
2 object state according to claim 23, which causes the
3 computer to further execute the steps of:
4 determining on the basis of the calculated
5 correction amount whether the object state set in
6 comparison image generation is appropriate;
7 outputting the object state set in comparison
8 image generation as an estimation value when it is
9 determined that the object state is appropriate; and
10 executing again estimation processing
11 including the step of generating the comparison image,
12 the step of detecting the positional relationship, and
13 the step of calculating the correction amount by setting

14 the calculated new object state to the predetermined
15 state when it is determined that the object state is not
16 appropriate.

25. An estimation program for estimating an
2 object state according to claim 24, which causes the
3 computer to execute, as the determination step, the step
4 of determining that the object state is appropriate when
5 the correction amount is smaller than a predetermined
6 amount, and determining that the object state is not
7 appropriate when the correction amount is not smaller
8 than the predetermined amount.

26. An estimation program for estimating an
2 object state according to claim 24, which causes the
3 computer to further execute:

4 the step of calculating a first similarity
5 between the comparison image and the input image after
6 the estimation processing is executed again;

7 the step of calculating a second similarity
8 between the comparison image and the input image before
9 the estimation processing is executed again; and

10 as the determination step, the step of
11 comparing the first similarity with the second
12 similarity, determining that the object state is not
13 appropriate when the first similarity is higher than the
14 second similarity, and determining that the object state
15 is appropriate when the first similarity is not higher
16 than the second similarity.

27. An estimation program for estimating an
2 object state according to claim 23, which causes the
3 computer to execute:
4 as the step of inputting the image, the step
5 of inputting a moving image containing an object; and
6 as the step of detecting the positional
7 relationship, the step of using a latest frame image of
8 the moving image as the input image.

28. An estimation program for estimating an
2 object state according to claim 23, which causes the
3 computer to execute, in the step of generating the
4 comparison image, the steps of:
5 reproducing a luminance value of an object
6 surface, which changes depending on an illumination
7 condition; and
8 generating the comparison image under an
9 illumination condition close to that for the input image
10 by using the reproduced luminance value.

29. An estimation program for estimating an
2 object state according to claim 28, which causes the
3 computer to execute, as the step of generating the
4 comparison image, the step of reproducing the luminance
5 value of the object surface by using an illumination
6 base image group representing a variation in luminance
7 of the object surface depending on the illumination
8 condition.

30. An estimation program for estimating an

2 object state according to claim 29, which causes the
3 computer to further execute the steps of:
4 measuring the 3D shape data of the object and
5 reflectance data of the object surface; and
6 calculating an illumination base image
7 representing the variation in luminance of the object
8 surface depending on the illumination condition by using
9 the 3D shape data and the reflectance data of the object
10 surface.

31. An estimation program for estimating an
2 object state according to claim 30, which causes the
3 computer to execute:
4 as the step of calculating the illumination
5 base image, the step of calculating a vector group
6 representing the luminance value of each point of the 3D
7 shape data under a plurality of illumination conditions,
8 obtaining a base vector group in descending order of
9 eigenvalues by principal component analysis of the
10 vector group, and outputting the base vector group as
11 the illumination base image group, and
12 as the step of generating the comparison
13 image, the step of obtaining a correspondence between
14 each point of the 3D shape data of the object and a
15 pixel of the image with the object being in an
16 estimation value at current time by using the 3D shape
17 data of the object, generating an image illumination
18 base group in which the illumination base image group is

19 projected to the image with the object being in the
20 estimation value by using the correspondence, and
21 generating, as the comparison image, an image nearest to
22 the input image by linear connection of the image
23 illumination base group.

32. An estimation program for estimating an
2 object state according to claim 23, which causes the
3 computer to execute, as the step of calculating the
4 correction amount, the step of calculating, as the
5 correction amount, a 3D motion of the object which
6 causes a moving amount of an object part corresponding
7 to each sub-region in the comparison image to be near to
8 an image displacement distribution by using the 3D shape
9 data of the object and the image displacement
10 distribution representing the positional relationship
11 between the comparison image and the input image for
12 each sub-region.

33. An estimation program for estimating an
2 object state according to claim 23, which causes the
3 computer to further execute:
4 the step of extracting an image feature amount
5 of each of the comparison image and input image on the
6 basis of luminance values of the comparison image and
7 input image; and
8 as the step of detecting the positional
9 relationship, the step of detecting the positional
10 relationship between the input image and the comparison

- 11 image for each sub-region on the basis of the image
- 12 feature amount.